

## Lecture No. 15

### Water Requirements

#### 15.1 Water requirement

It is defined as the quantity of water regardless of its source, required by a crop or diversified pattern of crops in a given period of time for its normal growth & development under field conditions at a given place. In other words it is the total quantity of water required to mature an adequately irrigated crop. It is expressed in depth per unit time.

Water requirement, if considered as a demand, it includes the quantity of water needed to meet the losses due to evapotranspiration (ET), plus the losses during the application of irrigation water (unavoidable losses) and the additional quantity of water required for special operations such as land preparation, transplanting, leaching of salts below the crop root zone, frost control etc.

$$WR = ET \text{ or } Cu + \textit{Application Losses} + \textit{Special needs}$$

It can also be expressed in supply terms as  $WR = IRR + ER + \Delta S + Gwc$

Where:

**IRR** = Total depth of irrigation water during crop life

**ER** = Effective rainfall received during crop life

**$\Delta S$**  = Profile water use i.e., difference in soil moisture in the crop root zone at the beginning and end of the crop

**Gwc** = Groundwater contribution, if any.

Water requirements of important field, vegetable and fruit crops are given in Table 15.1.

**Table 15.1. Water requirement of various crops**

Crop	Water requirement (mm)	Crop	Water requirement (mm)
Rice	1200	Tomato	600 – 800
Wheat	450 – 650	Potato	500 – 700
Sorghum	450 – 650	Pea	350 – 500
Maize	500 – 800	Onion	350 – 550
Sugarcane	1500 – 2500	Chillies	400 – 600
Sugarbeet	550 – 750	Cabbage	380 – 500
Groundnut	500 – 700	Banana	1200 – 2200
Cotton	700 – 1300	Citrus	900 – 1200
Soybean	450 – 700	Grapes	700 – 1200
Tobacco	400 – 600	Mango	1000 – 1200
Beans	300 – 500	Turmeric	1200 – 1400

Accurate crop water requirement data is essential in irrigated agriculture for:

- Economic appraisal of irrigation projects
- Design and operation of irrigation schemes
- Fixing cropping patterns and irrigated areas
- Irrigation scheduling to crops
- Efficient use of limited water

## 15.2 Irrigation requirement

It is the total amount of water applied to a cropped field for supplementing effective rainfall, soil profile and groundwater contribution to meet the crop water requirements for optimum growth. In other words irrigation requirement is exclusive of  $ER + \Delta S + Gwc$ .

$$IRR = WR - (ER + \Delta S + Gwc)$$

## 15.3 Net irrigation requirement

It is the amount of irrigation water just required to bring the soil moisture content in the effective crop root zone depth to field capacity. Thus, the net irrigation requirement is the difference in depth or percentage of soil moisture between field capacity and the soil moisture content in the root zone just before application of the irrigation water. in terms of depth, it can be expressed as:

$$NIR = \sum_{i=1}^n \frac{M_{fc} - M_{bi}}{10} \times \rho b_i \times ds_i$$

Where,

$NIR$  = Net irrigation requirement to be applied at each irrigation (mm)

$n$  = Number of soil layers considered in root zone depth  $ds$

$M_{fc}$  = Gravimetric moisture percentage at field capacity in  $i^{\text{th}}$  layer

$M_{bi}$  = Gravimetric moisture percentage just before irrigation in  $i^{\text{th}}$  layer

$\rho b_i$  = Soil bulk density in  $i^{\text{th}}$  soil layer ( $\text{g}/\text{cm}^3$ )

$ds_i$  = Depth of  $i^{\text{th}}$  soil layer (cm)

### Problem

From the data given below calculate the net irrigation requirement.

Soil depth (cm)	Field capacity (%)	Moisture content before irrigation (%)	Bulk density ( $\text{g}/\text{cm}^3$ )
0 – 25	21.4	14.5	1.45
25 – 50	20.5	13.4	1.47
50 – 75	18.6	15.2	1.51
75 – 100	18.5	15.5	1.54

**Answer:**

$$NIR = \frac{21.4 - 14.5}{10} \times 1.45 \times 25 = 25.01 \text{ mm}$$

$$NIR = \frac{20.5 - 13.4}{10} \times 1.47 \times 25 = 26.09 \text{ mm}$$

$$NIR = \frac{18.6 - 15.2}{10} \times 1.51 \times 25 = 12.83 \text{ mm}$$

$$NIR = \frac{18.5 - 15.5}{10} \times 1.54 \times 25 = 11.55 \text{ mm}$$

**NIR in soil profile (0 - 100 cm) = 25.01 + 26.09 + 12.83 + 11.55 = 75.48 mm**

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### **15.4 Gross irrigation requirement**

Though there are several irrigation systems and methods of water application to field crops, none of these methods are cent per cent efficient and it has been found that considerable water is lost during conveyance, distribution and application. Hence, excess water is needed than the actual crop water needs to offset these losses if any. Thus gross irrigation requirement is the total amount of water required to bring the crop root zone to field capacity (NIR) inclusive of the water required offsetting the application losses. Which in other words, NIR + Application & other losses. It can be calculated as follows:

$$GIR = \frac{NIR}{E_a} \times 100 = \frac{\text{Net irrigation requirement}}{\text{Irrigation Application Efficiency}} \times 100$$

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**Problem:**

- Given –
- a) Net irrigation requirement = 84.5 mm
  - b) Irrigation application efficiency = 65%
  - c) Calculate GIR

**Answer:**

$$GIR = \frac{84.5}{65} \times 100 = 130 \text{ mm}$$

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## 15.5 Irrigation interval

It is the number of days between two successive irrigations during the period without precipitation for a given crop and field. It depends on the crop ET rate and on the available water holding capacity of the soil in the crop root zone depth. Sandy soils require in general more frequent irrigations as compared to fine textured soils.

## 15.6 Irrigation period

It refers to the number of days that can be allowed for applying one irrigation to that of the next in a given design area during the period of highest consumptive use of the season. It is mathematically expressed as follows:

$$\text{Irrigation period (days)} = \frac{NIR}{\text{Peak period consumptive use}}$$

It is taken as the basis for designing irrigation system capacity. Irrigation systems are to be designed in such a way that the irrigation period is not greater than irrigation interval.

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### Problem:

- Given –
- a) Net irrigation requirement = 65.5 mm
  - b) Peak period  $C_u$  = 7.2 mm
  - c) Calculate irrigation period

### Answer:

$$\text{Irrigation period} = \frac{65.5}{7.2} = 9.1 \sim 9 \text{ days}$$

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## Lecture No. 16

### Duty of Water And Conjunctive Use of Water

#### 16.1 Duty of water

It is the relationship between the irrigation water and the area of the crop that matures fully with the given amount of water. Duty is expressed as follows:

1. Area per unit rate of flow (ha/cumec)
2. Depth of water or Delta (ha/depth of water)
3. In terms of stored water (ha/million m<sup>3</sup> of stored water)

##### 16.1.1 Base period

The time between first irrigation to a crop at sowing or planting and last irrigation before harvest on a given field.

##### 16.1.2 Relationship between duty, delta and base period

- Let there be a crop of base period 'B' period
- Let 1 cumec of water be applied to this crop on the field for 'B' days.
- The total quantity of water applied in 'B' days = 1 x B x 24 x 60 x 60 m<sup>3</sup>.
- Let this be equal to V = 1 x B x 24 x 60 x 60 m<sup>3</sup>
- Let V m<sup>3</sup> of water bring to maturity 'D' ha of land A = D x 10000 m<sup>2</sup>

$$\text{Delta } (\Delta) = \frac{V}{A} = \frac{B \times 24 \times 60 \times 60}{D \times 10000} = 8.64 \frac{B}{D} \text{ m} = 864 \frac{B}{D} \text{ cm}$$

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#### Problem

A tank has a water spread area of 40 ha with an average depth of 3m of water. Calculate the area of rice (120 days base period) that can be irrigated if the duty is expressed as:

a) 960 ha m<sup>3</sup>/sec; b) 110 ha cm; and c) 90 ha/million m<sup>3</sup> of water.

**Answer:**

**Total available water = 40 x 3 x 100 ha.cm**

$$\text{Delta} = \frac{B}{D} \text{ cm} = 864 \frac{120}{960} = 108 \text{ cm}$$

$$\text{Area} = \frac{40 \times 3 \times 100}{108} = 111 \text{ ha}$$

$$Area = \frac{40 \times 3 \times 100}{110} = 109 \text{ ha}$$

$$Area = \frac{40 \times 1000 \text{ m}^2 \times 3}{10,00,000} = 1.2 \text{ million m}^3 \times 90 \text{ ha} = 108 \text{ ha}$$

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## 16.2 Conjunctive Use of water

It is estimated that in India about 11 million ha m of water diverted from reservoirs is lost through seepage and percolation from canal systems and return flows from irrigation contribute to ground water recharge. This water can be extracted and conjunctively used for irrigation in part of command areas to tide over the peak demands and water shortages.

Conjunctive use refers to “management of multiple water resources in a coordinated operation such that the water yield of the system over a period of time exceeds the sum of yields of the individual components of the system, resulting from in coordinated operation”.

### 16.2.1 Systems of conjunctive use

1. Canal water and Groundwater system
2. Rainfall and Irrigation water system
3. Saline water and Fresh water system

### 16.2.2 Conjunctive use – Advantages

- a) Use of ground water helps to reduce peak demands of irrigation, size of canals and hence construction costs
- b) Supplemental supplies from groundwater ensures proper irrigation scheduling raising multiple crops and early sowing even if rainfall is delayed
- c) Increased water resources ensure supply to tail end areas and areas of higher elevation
- d) Groundwater exploitation lowers the water table and reduces danger of water logging and consequent wastage of water for leaching salts
- e) Surface and subsurface out flows are minimized causing reduction in peak run off and flood discharge
- f) Conjunctive use when integrated with an artificial recharge project, need for lining canals is reduced as seepage from canal recharges ground water
- g) During periods of peak water demand, irrigation requirement can be met by surface water sources, so power saved can be diverted to other sources

## Lecture No. 17

### Effective Rainfall

#### 17.1 Introduction

The primary source of water for agricultural crop production in most parts of the world is rainfall. All the rainwater, however, cannot be useful for crop production. The extent of the rainfall received and its utility in crop production in a given location determines its effectiveness. In simplest terms, effective rainfall means useful or utilizable rainfall. From the point of view of the crop water requirement Dastane (1974) has defined effective rainfall as **“that portion of the total annual or seasonal rainfall which is useful directly and/or indirectly for meeting the crop water needs in crop production at the site where it falls but without pumping”**. It therefore includes water intercepted by living or dry vegetation, that lost by evaporation from puddles on soil surface, lost by evapotranspiration during crop growth, that fraction which contributes to leaching & percolation or facilitates other cultural operations either before or after sowing without any harmful effect on yield and quality of the field crops. Consequently ineffective rainfall is that portion, which is lost by surface runoff, unnecessary deep percolation losses, the moisture remaining in the soil after the harvest of the crop and which is not useful for the succeeding crop. This concept of effective rainfall is suggested for use in planning and operation of irrigation projects.

#### 17.2 Factors influencing Effective Rainfall

Several factors influence the proportion of effective rainfall in the total rainfall received and these may act singly or collectively and interact with each other. Any factor, which affects infiltration, run-off or evapotranspiration, affects the value of effective rainfall. The following factors have been shown to influence the effective rainfall significantly:

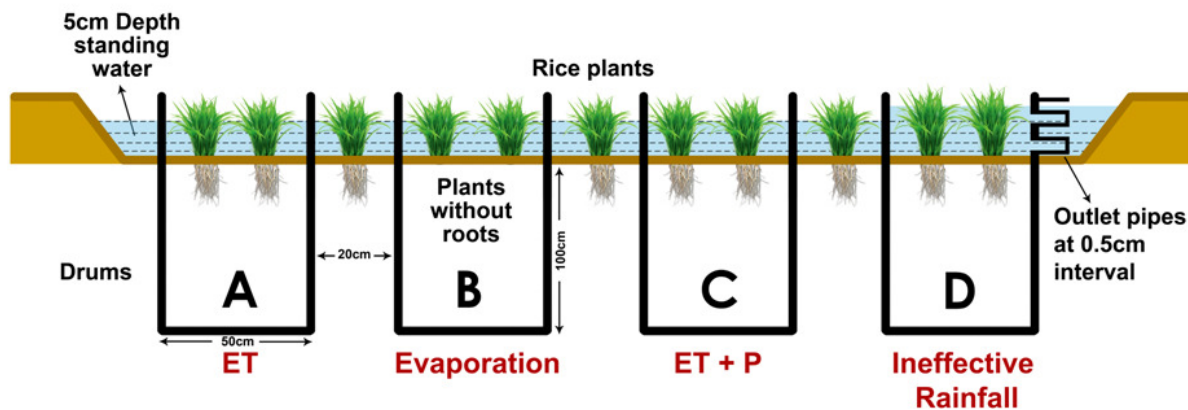
- a) **Rainfall characteristics:** Amount, intensity and distribution of rainfall influence surface runoff and hence its effectiveness. Greater amount of rainfall at high intensities reduce the effective fraction of the rainfall. Similarly, uneven distribution decreases the extent of effective rainfall. In India during *kharif* season from July to September the rainfall intensity, frequency and amount is high, hence the effectiveness of rainfall is very low. On the other hand, during winter season from November to April, most of the rainfall is effective due to its low intensity, frequency and amount. Other meteorological parameters which increase the ET increase the effectiveness of the rainfall. Higher evaporative demand of the atmosphere encourages greater depletion of moisture in the soil and therefore the proportion of effective rainfall in the total increases.
- b) **Land characteristics:** The time interval between receipt of rain water and its recession by soaking into soil is known as opportunity time. Water stays longer on flat and

leveled land and this has longer opportunity time than on slopping land, leading to higher fraction of effective rain than on undulating lands.

- c) **Soil characteristics:** Higher infiltration and permeability rates increase effectiveness of rainfall. Fraction of the effective rainfall increases with increasing water holding capacity of the soil. The proportion of effective rainfall is lower in irrigated than the unirrigated areas where there is often greater deficiency of soil moisture.
- d) **Ground water characteristics:** The amount of effective rainfall is greater when the water table is deep than when it is shallow. Upward capillary movement of water decreases the deficit of moisture and hence the amount of effective rainfall.
- e) **Management practices:** Any management practice influencing runoff, infiltration, permeability or evapotranspiration also influences the degree of effective rainfall. Bunding, terracing, ploughing, ridging and mulching reduce runoff and increase effective rainfall.
- f) **Crop characteristics:** Higher crop ET rates create greater depletion of soil moisture. Hence, effective rainfall is directly proportional to the rate of water uptake by the crop. Degree of ground cover, root zone depth and growth stage influences the rate of water uptake. Rainfall which reduces the yield (such as downpours which often cause lodging in cereals when the latter are at the grain formation stage) must be regarded as ineffective

### 17.3 Drum culture technique

This method was devised by Dastane et.al., (1966) for assessing crop evapotranspiration, percolation, effective and ineffective rainfall of a rice crop simultaneously under the field conditions (Fig. 17.1).



**Fig. 17.1. Drum culture technique for assessing water balance components in rice**

Four containers (metallic drums) A, B, C and D of about 40 gallons (182 liters) capacity (50cm in diameter and having 125cm height) are embedded in a rice field, leaving about 31 to 32 cm of their height above ground level. The bottoms of drums C and D are



removed, thus allowing percolation below the root zone. Further for drum D outlet pipes are fitted at 0.5cm intervals to the above 31 – 32 cm for precise water control. These outlet pipes can be connected to a water receiver. The drums are filled with the representative soil compacted to field density and rice seedlings are transplanted in drum A, C and D, along with the adjoining field crop. Whereas in drum B rice plants are transplanted every week selected from the bulk crop surrounding the drums. However before transplanting remove the roots of rice plants. These rootless plants in drum B shade the soil as plants in other drums and affect the evaporation. Water levels in the drums are maintained at the same level as outside.

The drum D is intended to measure the ineffective rainfall. The height of the rice crop and height of the field bunds govern the maximum depth of submergence, whichever is less. Any rainfall which submerges the crop beyond a predetermined level or which exceeds the height of the bunds is ineffective. As the height of the crop increases, the outlets are plugged till the bund height becomes the limiting factor. The water level is set at a selected height in drum D. This height can be adjusted with increase in growth of plants. Evapotranspiration and percolation continue and create a deficit every day. When rain falls, it first makes up this deficit and the surplus flows out through the outlet pipes, this is termed as ineffective rainfall. If there are no rains, the water level in drum D will gradually reach the soil surface and the crop will be irrigated according to normal practice. Water level in the drums is measured every day and losses due to ET and percolation are replaced.

- a) Difference in water level in drum A = Daily Evapotranspiration
- b) Difference in water level in drum B = Daily Evaporation
- c) Difference in water level in drum C = Total daily water needs
- d) Difference in water level between drum A and B = Daily Transpiration
- e) Difference in water level between drum A and C = Daily Percolation losses
- f) Ineffective rainfall = Water collected in receiver tank from outlet pipes of drum D
- g) Effective Rainfall = Total rainfall received – Ineffective rainfall